BECKMAN COULTER
Life Sciences

Monitoring Compressed Gases with the MET ONE 3400+ Air Particle Counter

Abstract

The MET ONE 3400+ Portable Air Particle Counter has been demonstrated to effectively monitor commonly used compressed gases for total particle counts and cleanliness. Although the instrument does not automatically compensate for gases other than Clean Dry Air (CDA) and Nitrogen, results for other gases can be adjusted using a simple calculation. This application note outlines the equipment required for compressed gas monitoring, the MET ONE 3400+ instrument configuration for accurate sampling, and the interpretation of the generated results. Beckman Coulter Life Sciences conducted a characterization study to support the use of scaling factors for monitoring Clean Dry Air, Nitrogen, Carbon Dioxide, and Argon with the MET ONE 3400+ Air Particle Counter.

Equipment

Overview of Equipment

- High-Pressure Diffuser (Beckman PN 2080732-13 for 28.3 LPM)
- MET ONE 3415+ Air Particle Counter (PN C38678) or MET ONE 3413+ Air Particle Counter (Beckman PN C38675)
- Gas and quality grade
- Pressure regulator
- Hytrel tubing (Beckman PN C64713)
- Fittings as required to adapt #4 vacuum coupling radius fittings (VCR) on the High-Pressure Diffuser to your gas system

Compressed gas at pressures ranging from 206.8 kPa (30 PSI) to 1034.2 kPa (150 PSI) can be monitored using a MET ONE 3400+ Portable Air Particle Counter in conjunction with the MET ONE High-Pressure Diffuser (HPD). If the pressure exceeds 1034.2 kPa (150 PSI), a regulator should be employed to reduce the pressure to approximately 206.8 kPa (30 PSI). Operating the HPD at higher pressures will increase noise and excessive gas loss. This application note is not intended to replace the necessity of reading and adhering to all precautions outlined in the HPD Instructions.[1]

The HPD inlet is connected to the gas supply, and the outlet barb is connected via 3/8″ tubing, up to 1 meter in length, to the 3/8″ barb inlet of the 3400+ instrument. When the gas testing valve is opened, excess gas will flow out of the HPD's exhaust port. When the 3400+ Air Particle Counter is set for sampling, ensure that gas continues to flow out of the exhaust port. Any gas entering the exhaust can contaminate the gas flow and result in an incorrect particle counting reading.

Sample Configuration: MET ONE 3400+ Air Particle Counter

The MET ONE 3400+ instrument can be configured for manual or standard operating procedure (SOP) sampling. The use of SOP sampling is recommended to fully capture all metadata associated with the gas. Configuring each gas as a separate SOP allows for the sampling time and alarm levels to be inherited by all the locations contained in the SOP. The building level can group SOP locations into logical and physical groups (e.g., physical buildings or rooms). Each sampling port in the lab to be tested can be configured as an individual location to appropriately tag the data for future analysis.

The type of gas sampling can impact the volume or time and alarm levels at the SOP level. Depending on the gas used, the desired volume or sampling time should be scaled appropriately. The scale factors listed below are provided by the manufacturer (Siargo Ltd. CA, USA) for the FS1015 flow meter model used in the 3400+ Air Particle Counter.[2] These factors adjust the measured air volume to reflect the actual volume of air sampled. Beckman Coulter Life Sciences characterized these scale factors experimentally.

Gas	Clean Dry Air (CDA)	Nitrogen (N_2)	Carbon Dioxide (CO_2)	Argon (Ar)
Scale Factor	1.00	1.00	0.70	1.2
Actual Volume when instrument reads 0.0283 m^3 of gas	0.0283 m^3	0.0283 m^3	0.0198 m^3	0.0340 m^3
Nominal time for instrument to reach a 0.0283 m^3 reading	1 minute	1 minute	1 minute	1 minute
Volume to sample to get 0.0283 m^3 of gas	0.0283 m^3	0.0283 m^3	0.0404 m^3	0.0236 m^3
Nominal time to sample 0.0283 m^3 of gas	1 minute	1 minute	1 minute 26 seconds	50 seconds
Volume to sample 1 m^3 of gas	1 m^3	1 m^3	1.4286 m^3	0.8333 m^3
Nominal time to sample 1 m^3 of gas	35 minutes 34 seconds	35 minutes 34 seconds	50 minutes 29 seconds	29 minutes 27 seconds

Table 1. Gas scaling factors from the Mass Flow Meter Manufacturer and the associated calculated sample volumes and times.

Note that the particle counter complies with ISO 21501-4, which specifies flow to be within ±5% of the nominal flow rate.[3] If the instrument is configured for volume sampling, the sample time could vary by ±5%, and if the instrument is configured for time sampling, the volume could vary by ±5%.

For example, if you needed to take a 0.0283 m^3 (28.3 l / 1 ft^3) sample of CO_2, you would configure the instrument to take a 0.0404 m^3 sample.

As a second example, if you normally take a one-minute sample to take a nominal 0.0283 m^3 (28.3 L / 1 ft^3) sample of CO_2, you would configure the instrument to take a one-minute and 26-second sample to achieve the same measurement.

As a third example, if you needed to take a 0.0283 m^3 (28.3 L / 1 ft^3) sample of argon, you would configure the instrument to take a 0.0236 m^3 sample. Most regulations require a one-minute minimum sample time, so you can set the instrument to take a one-minute sample and note the actual volume of approximately 0.0340 m^3 (34.0 L) of gas.

The alarm limits should also be scaled once the volume or time has been set appropriately. For clarity, only raw count alarms should be used. If your gas sampling limits are expressed in concentration (typically, they are either from ISO 8573-1 or EU GMP Annex 1), then the limit must be scaled to the actual volume of gas measured.

For example, if the alarm limit is 3,520 particles per cubic meter in CO_2, and a 0.0404 m^3 sample was programmed (yielding 0.0283 m^3 [28.3 L] of CO_2 sampled), then the Raw Count alarm limit for this configuration would be:

$$\frac{\textbf{3,520 particles}}{\textbf{1 m}^3\ \textbf{CO}_{2\ (g)}} \times 0.0283\ \textbf{m}^3\ \textbf{CO}_{2\ (g)} = 99.6 \cong 100\ \textbf{particles}$$

We achieve this result with dimensional analysis, where the input alarm limit can be converted into raw particle counts by multiplying it by the volume of CO_2 sampled when considering the scaling factor.

As another example, if the alarm limit is 29 particles/m^3 in CO_2, and a 1.4286 m^3 sample was programmed (yielding 1.000 m^3 of CO_2 samples), then the Raw Count alarm limit for this configuration would be:

$$\frac{\textbf{29 particles}}{\textbf{1 m}^3\ \textbf{CO}_{2\ (g)}} \times 1\ \textbf{m}^3\ \textbf{CO}_{2\ (g)} = 29\ \textbf{particles}$$

For low concentration limits like these, larger volume samples can be required to ensure high purity limits are achieved. Scaling the measured volume to compensate for the desired volume makes the result more intuitive.

To identify the actual volume sampled, we recommend using the **User Defined Field** to set up an **Actual Volume** field that has a default value of the scaled volume sampled. This will indicate to any user that the volume reading should be scaled.

For example, the volume measurement setting could be configured for 0.0404 m^3 of CO_2, and the User-Defined Field **Actual Volume** would have a default value of 0.0283 m^3 / 28.3 L.

Other SOP features, such as Fleet-Managed Sample Timeouts, User-Defined Fields, and Replicate (Multiple) Samples, will work the same as in any other SOP.

Interpretation of Results

When the MET ONE 3400+ Portable Air Particle Counter is configured as described above, the actual sample volume will be scaled by the scale factor **(Table 1)** for the gas sampled. This is shown in formula form as:

$$\textbf{Actual Volume} = \textbf{Measured Volume} \times \textbf{Scale Factor}$$

Note that since the Scale Factor is unitless, the actual volume and measured volume will have the same units (cubic meters or cubic feet).

The same scaling would also apply to the flow measurement:

$$\textbf{Acutal Flow Rate}_{\textbf{compressed gas}} = \textbf{Measured Flow Rate}_{\textbf{Air}} \times \textbf{Scale Factor}$$

Again, the Actual Flow Rate will have the same units as the Measured Flow Rate (L/min or ft^3/min).

When a flow calibration is performed with air and then gases such as CO_2 and argon are sampled, gas velocity through the particle counter will be impacted. The flow is impacted because the mass and thermal properties of the gases vary from those of air. As particles spend more or less time in the focused laser beam used for particle sizing and detection, their measured and counted size will vary.

In clean, dry air and N_2, the velocity of the gas is the same as air, so the particle sizing calibration done in air is maintained, and particle count results can be used with no scaling.

In CO_2, the gas will flow more slowly through the beam. As a result, 0.500 µm particles will appear 14% (± 5.8%) larger at around 0.581 µm. Particles as small as 0.430 µm will be counted as 0.5 µm or larger. Note that this 14% factor will vary by particle counter and calibration, but the result will always be that the counts observed in the 0.5 µm channel will be higher than the actual 0.5 µm counts in the CO_2 gas. Thus, an end-user seeing counts on their 3400+ Air Particle Counter lower than the purity standard they are working to can be assured that the actual counts are even lower than measured.

In argon, the gas will flow more quickly through the beam. As a result, 0.500 µm particles will appear approximately 6.2% (± 5.8%) smaller at around 0.470 µm. Only particles 0.531 µm and larger will be counted as 0.5 µm, or larger; particles between 0.500 and 0.531 µm will not be counted unless the instrument is a MET ONE 3413+ Air Particle Counter with a 0.3 µm channel configured. The 0.3 µm channel variation was characterized at 3.0% (±5.8%), so the 0.3 µm channel would measure particles 0.309 µm and larger. (Note that these scale factors at 0.5 and 0.3 µm will vary by instrument and calibration). Regardless of the size, the particle counts measured in each channel size by the 3400+ Air Particle Counter would always be lower than the actual counts of particles in the argon gas sampled. An end user measuring in argon would have to analyze the impact of these size variations and determine if the 0.3 µm channel and its much higher particle counts could be used in place of a 0.5 µm purity standard. At 0.5 µm, we expect the particle counts to be 11.5% lower than the actual counts measured. Proper scaling of the cleanliness standard would need to be applied.

Conclusion

The MET ONE 3400+ Portable Air Particle Counter has been demonstrated to monitor some commonly used compressed gases for total particle counts and cleanliness. Scale factors provided by the manufacturer of the flow meter used in the instrument were experimentally characterized by Beckman Coulter Life Sciences using a calibrated volume displacement meter. Applying these scale factors to the volume of a sample yields accurate measurements of the actual volume sampled. Using the volume sampling mode of the MET ONE 3400+ instrument is recommended for consistently scaled volumes.

For gases like CO_2 and argon, the velocity of gas and particles through the sensor will change, yielding a shift in the calibration curve. For CO_2, the 3400+ Air Particle Counter will overcount actual particles of a given channel size, while for argon it will undercount actual particles of a given channel size. Appropriate consideration of the cleanliness standards should be applied to ensure excursions are properly captured and analyzed.

Your Beckman Coulter Sales Specialist team can assist in analyzing your specific gas monitoring needs and recommend the appropriate equipment and sampling configuration to obtain results that meet your quality standards.

References

1. MET ONE High Pressure Diffuser, User Manual. DOC026.97.80307. Edition 3 (October 2023).
2. Technical White Paper: Gas Conversion Factor for Thermal Mass Flow Sensing Products [White paper]. Siargo Ltd (CA, USA).
3. ISO 21501, Determination of particle size distribution, Single particle light interaction methods –Part 4: Light scattering airborne particle counter for clean spaces.

This application note characterizes the use of the MET ONE 3400+ Air Particle Counter to monitor compressed gases; it is for demonstration only and is not validated by Beckman Coulter. Beckman Coulter makes no warranties, express or implied, with respect to this protocol, including warranties of fitness for a particular purpose or merchantability or that the protocol is non-infringing. Your use of the method is solely at your own risk, without recourse to Beckman Coulter.

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